Summary. Seattle supports in principle the requirements in the Draft Permit for Stormwater Management Program Effectiveness Monitoring (Section S8.B) and Stormwater Treatment and Hydrologic Management Best Management Practices (BMP) Evaluation Monitoring (Section S8.C). Seattle agrees that results from these monitoring programs are likely to provide a feedback loop for adaptive management of the permittees' stormwater management programs and the municipal stormwater permit, the primary objective of the NPDES Stormwater Monitoring Program (Fact Sheet, page 49, lines 2-3). However, we believe that the Stormwater Monitoring (Section S8.A) is highly unlikely to provide results that support adaptive management of any permittee's stormwater management programs or the municipal stormwater permit. Therefore, Seattle recommends that it be removed in its entirety as a requirement of the permit. Additional details are provided below and in Attachments 6B and 6C.

Comments on Special Condition S8 in Draft Permit.

1. Section S8.A Stormwater Monitoring – Summary of Seattle's Recommendation

   The Stormwater Monitoring Program as presented in Section S8.A is technically infeasible to successfully implement. The technical difficulties with the current requirements are related to the number of storms required per year, the distribution of storms between dry and wet seasons, and the duration of the storm event to be sampled. These three items are discussed below.

   Number of Storms Required. The number of required storms per year (15) is too high. From a feasibility standpoint, Seattle recommends 75% of qualifying storms up to a maximum of 10 storms/year. This lower number is based on a realistic understanding of the challenges associated with tracking weather, predicting storm sizes, estimating pacing rates, and accounting for equipment malfunctions. It is also based on Seattle's experience with stormwater sampling programs (including Ecology's TAPE-designed programs) implemented by experienced consultants. Based on Seattle's experience using a 0.15" storm criteria (the TAPE protocol criteria) and planning to target for sampling almost every storm event forecasted to meet criteria, Seattle anticipates being able to sample 10 to 12 events per year. In the Fact Sheet (Page 49, lines 15-17), Ecology indicates that based on monitoring experiences by the City of Tacoma, Ecology anticipates that collecting data from 15 events per year is readily achievable. However, the City of Tacoma has been, on average, only able to collect 10 stormwater samples per year using a 0.2" criteria and does not agree that 15 events per year is a reasonable requirement (D. DeLeon, pers. comm., 5/8/06). Reducing the storm size criterion from 0.2" to 0.1" does not make it easier to meet the required number of storms per year because of the following reasons:

   - Small storms (<0.2") often do not generate enough runoff to sample successfully. This is especially true if drainage basins are small, as they would likely be to meet the permit's requirements to be representative of a single land use.
   - Small storms are particularly difficult to target for sample collection since they are often more localized and storm forecasting methods are less reliable for smaller events.

- Lowering the storm size criteria creates that many more storms for which Permittee would be required to sample 75%.

Distribution of storms between dry and wet seasons. It will be difficult to ratio the number of wet season to dry season samples, and it is not necessary. Seattle recommends requiring a specific number of storms in wet season and dry season instead of a ratio between seasons. From a feasibility standpoint, Seattle recommends that 75% of qualifying storms with a maximum of 8 storms/year be required during the wet season. Seattle recommends that 75% of qualifying storms with a maximum of 2 storms/year be required during the dry season.

Required duration of storm to be sampled. It is not possible to sample 100% of the storm volume due to equipment limitations and malfunctions, flow pacing estimations based on unreliable weather forecasts, and long duration storms (e.g., between January and early March 1999, it rained in Seattle for 48 of 53 days). Seattle recommends a requirement to sample 75% of the total storm runoff volume if the storm lasts for less than 24 hours, and if the storm is longer then 24 hours, a requirement to sample the first 24 hours of the storm runoff volume. This recommendation is based on the TAPE protocol (p.17), "As a guideline, at least 10 aliquots should be composited, covering at least 75% of each storm's total runoff volume up to the design storm volume."

All of the recommendations above reflect what changes would be necessary to the permit language to make Section S8.A Stormwater Monitoring *technically* feasible to implement. However, Seattle believes that conducting EMC-based trend monitoring is unlikely to achieve its primary objective regarding adaptive management of either the permittees' stormwater management programs or the municipal stormwater permit and should, therefore, be dropped from the permit as a requirement. The reasons for this recommendation are summarized below.

1. Stormwater runoff concentrations are highly variable, capable of spanning several orders of magnitude at a single site.
2. Owing to this variability, a significant amount of data must be collected over many years before a trend can be determined. On a per-site basis, our estimates indicate that the number needed ranges from many hundreds to several thousands of samples per site for each parameter of interest.
3. The costs involved in collecting these data will draw funds away from other stormwater programs. Seattle estimates implementation (i.e., data collection) for S8.A will cost between $225,000 and $276,000 per year (Attachment 6C). Using a conservative (i.e., low) range estimate of between $100,000 and $200,000 per year per permittee, the estimated net present value of the data collection effort of all Phase I Permittees over a period spanning many years exceeds nearly $200,000,000 and is probably much higher.
4. Even if a trend could be determined at the cost estimated above, it is unclear the degree to which this trend would actually influence decision-making at the programmatic and regulatory scale.

To give Ecology more information about the implications of requirements S8.A (Stormwater Monitoring), Attachment 6B provides an expanded discussion of the issues using statistical analysis and illustrative examples. Attachment 6C includes Seattle's cost estimate to implement the proposed requirements of Section S8.A.

Seattle supports monitoring when it is likely to provide useful information. Given the concerns expressed above and explained further in Attachment 6B, Seattle believes that there is a high risk that the monitoring requirement of S8.A will result in a high cost over a long period of time and yet result in little, if any benefit to Ecology, the Permittees, or the environment. Therefore, Seattle recommends the S8.A requirement be eliminated in its entirety. However, if Ecology chooses to incorporate such risks into the permit, Seattle recommends mitigating the risks by lowering the mandatory level of effort. If the requirement is retained, Seattle recommends that Ecology reduce the number of required representative sites from three to two, and require 75% of qualifying storms up to a maximum of 8 storms/year during the wet season and 75% of qualifying storms up to maximum of 2 storm/year during the dry season.

2. Page 36, line 19, Section S8 and Pages 36-39, Section S8A. Seattle recommends removing Section S8.A Stormwater Monitoring from permit. If Stormwater Monitoring is to be required, Seattle recommends incorporating comments/changes described below.

3. Page 37, line 38 – Page 37, line 8, Sections S8.A.1.b and S8.A.1.c. Seattle recommends including roadway as a land use since in urban environments it can represent up to 25% of land area. Seattle also recommends requiring permittees to select and monitor two of the four listed land uses with an option of selecting (i.e., pairing) two locations representing the same land use. Monitoring at two locations would allow for comparison of basins with similar land use to investigate any observed differences in EMCs between the two land uses. Seattle recommends modifying permit Section S8.A.1.b as follows:

   "b. Counties shall monitor at two outfalls or conveyances. Each monitoring station will be representative of one of the following land uses. Permittees may establish monitoring stations at two different land uses or establish monitoring stations at two sites having the same land use in a paired watershed approach:

      i. Commercial,
      ii. Low density residential,
      iii. High density residential, and
      iv. Roadway"

   Seattle recommends modifying permit Section S8.A.1.b as follows:

   "c. Cities shall monitor at two outfalls or conveyances. Each monitoring station will be representative of one of the following land uses. Permittees may establish monitoring stations at two different land uses or establish monitoring stations at two sites having the same land use in a paired watershed approach:

      i. Commercial,
      ii. High density residential,
      iii. Industrial, and

iv. Roadway."

4. Page 37, lines 13-30, Section S8.A.2.a.i. As discussed previously, Seattle recommends requiring <u>sampling 75% of qualifying storms up to a maximum of 8 storms/year during the wet season</u>. Seattle recommends <u>requiring 75% of qualifying storms up to a maximum of 2 storms/year be required during the dry season</u>. Seattle recommends modifying permit Section S8.A.2.a.i as follows:

   "a. Each stormwater monitoring site shall be sampled according to the following frequency:

   i. 75% of the qualifying storms during the wet season, from October 1 through April 30, up to a maximum of 8 storm events per year. A wet season storm event is defined as follows:

      - Rainfall volume 0.10" minimum
        No fixed maximum
      - Rainfall duration No fixed minimum or maximum
      - Antecedent dry period less than 0.02" rain fall in the previous 24 hours
      - Inter-event dry period 6 hours

   ii. 75% of the qualifying storms during the dry season, from May 1 through September 30, up to a maximum of 2 storm events per year. A dry season storm event is defined as follows:

      - Rainfall volume 0.10" minimum
        No fixed maximum
      - Rainfall duration No fixed minimum or maximum
      - Antecedent dry period less than 0.02" in the previous 72 hours
      - Inter-event dry period 6 hours"

5. Page 37, lines 31-34, Section S8.A.2.b. As discussed previously, Seattle recommends requiring that flow-weight composite storm sampling be required to sample 75% of the total storm runoff volume if the storm duration is less than 24 hours. If storm is longer then 24 hours, then require sampling the first 24 hours of the storm runoff volume. Seattle recommends modifying permit Section S8.A.2.b as follows:

   "b. Each sampled storm event should be sampled using flow-weighted composite storm sampling. As a guideline, at least 75% of the total storm runoff event volume should be sampled if the storm duration is less than 24 hours. If the storm is longer than 24 hours, 75% of the total runoff event volume of the first 24 hours should be sampled. Samples should be analyzed for the constituents presented below. Chemicals that are below detection limits after two years of data may be dropped from the analysis."

6. Page 38, line 3, Section S8.A.2.b.iii. Seattle recommends that conductivity be measured in all samples. It is an inexpensive measure that can be useful in evaluating groundwater inputs and illicit discharges at non-tidally influenced locations. Recommended change:

   "iii. Conductivity"

7. Page 38, lines 26 – 33, Section S8.A.2.e. Seattle recommends removing non-water quality monitoring requirements from the permit. The scope of NPDES required monitoring should be limited to water quality parameters. Recommend deleting section.

8. Page 39, lines 6-9, Section S8.B.1. Seattle recommends rewording for clarity if this meets Ecology's intent. Recommended change:

   "… shall develop and implement two monitoring programs. One monitoring program will address the effectiveness of a targeted action (or narrow suite of actions), and one monitoring program will address the effectiveness of achieving a targeted environmental outcome."

9. Page 39, lines 12-15, Section S8.B.2. Seattle recommends deleting the requirement that mandates either stormwater or receiving water monitoring as part of the Stormwater Management Program Effectiveness Monitoring. The goal of the Stormwater Management Program Effectiveness Monitoring is "to determine the effectiveness of the Permittee's SWMP at controlling a stormwater related problem directly addressable by action in the SWMP" (page 39, lines 5-6). Seattle disagrees that "monitoring of stormwater or receiving water is necessary" (Fact Sheet, page 52, lines 11-12) or even useful to determine effectiveness. A program can be effective in reducing a pollutant discharge, but the reduction may not be detectable in stormwater or the receiving water body due to the inherent variability in stormwater samples discussed previously. Additionally, for some stormwater management programs, surrogate measures other than stormwater or receiving water analysis are appropriate. As an example, consider a public education program designed to reduce the use of pesticides in an urban area. Such a program would be based on the reasonable assumption that if fewer pesticides are being sold to end users, then fewer pesticides are being released into the environment. It is highly unlikely that this change would be able to be detected by stormwater or receiving water sampling. However, the effectiveness of such a program could be evaluated by monitoring sales of targeted pesticides over time and conducting spot surveys of target users.

   If Ecology chooses to require types of monitoring, Seattle recommends adding sediment monitoring as an option (along with stormwater and receiving water). Many toxic components are difficult to measure in stormwater discharges. Sediment samples may be a better media for determining presence/absence of these compounds. If Ecology is going to required types of monitoring, recommended change:

   "2. The monitoring may include stormwater, receiving water, or sediment monitoring of physical, chemical, and/or biological characteristics. The monitoring may also include data collection and analysis or other programmatic measures of effectiveness such as surveys and polls."

10. Page 40, lines 15-19, Section S8.C.2.b. Comment. To complete the BMP effectiveness monitoring within the timeline presented in later comments, monitorable BMPs designed to 2005 SWMM standards would need to be in the ground at the time the permit is issued.

11. Page 40, lines 15-19, Section S8.C.2.b. Seattle recommends allowing monitoring of low impact development water quality BMPs listed in the Low Impact Development Technical Guidance Manual for Puget Sound (PSAT, 2005) to meet the requirements of Section S8.C. Seattle currently has none of the listed BMPs designed to 2005 SWMM standards in the ground and, due to Seattle's ultra-urban setting, does not anticipate installing any in the near future. Seattle has expertise in designing, installing, and monitoring innovative stormwater treatment technologies utilizing bioretention and flow control strategies (e.g., natural drainage systems). Recommended change:

    "b. BMPs shall be designed in accordance with the 2005 Stormwater Management Manual for Western Washington unless Ecology approves of an alternate design in the QAPP review. Instead of the BMPs listed in S8.C.2.a, a Permittee may select to monitor the effectiveness of water quality low impact development (LID) BMPs listed in the Low Impact Development Technical Manual for Puget Sound such as bioretention areas, amending construction site soils, and permeable paving. Permittees may also petition Ecology to monitor a BMP that is not on the above list that they wish to evaluate as a potential option for common use in their jurisdiction."

12. Page 40, lines 28, Section S8.C.2.c. Please clarify what is intended by "80% power" or delete the phrase.

13. Page 42, lines 2-4, Section S8.D.2. Seattle recommends that all monitoring program QAPPs be reviewed and approved by Ecology. At a minimum, the review should confirm that the monitoring approaches meet the requirements put forward in Section S6 and Ecology's requirements for QAPPs. Recommended change:

    "2. All QAPPs must be submitted to Ecology, for approval, in accordance with the deadlines below. All QAPPs must be reviewed and approved by Ecology prior to monitoring."

14. Page 42, lines 15-16, Section S8.E.1.c. Seattle recommends establishing timeline for Permittee to respond to Ecology comments on QAPP instead of timeline for approved QAPP. The Permittee does not have control over when Ecology comments on or approves the submitted QAPPs. Given that each Phase I Permittee may be submitting up to 8 QAPPs to Ecology for review, it may be challenging for Ecology to complete review and approval in six months. In addition, if Ecology takes six months to review and provides comments at that time, the Permittees will need time to incorporate into final QAPP and resubmit for approval. Seattle also recommends that all monitoring programs must be implemented within six months after the QAPP has been approved by Ecology or within 24 months after the effective date of the permit for independent monitoring programs (36 months for collaborative monitoring programs), whichever is later. This is to still provide time for Permittee to plan for and mobilize resources if Ecology has a quick turnaround (i.e., less than six months) on QAPP approval. Recommend changing S8.E.1.c to the following:

> "c. Ecology will review QAPPs and provide a written response to the Permittee. If Ecology requests additional information or changes to the QAPP, the Permittee will revise the QAPP within 2 months of receiving written comments from Ecology and resubmit QAPP for approval. Ecology will review resubmitted QAPPs and provide a written response to the Permittee."

15. Page 42, lines 17-18, Section S8.E.1.c. Seattle recommends linking implementation of the monitoring program to approval of the QAPP (see previous comment). Also, Seattle also recommends removing reference to receiving water monitoring program as Permittees monitoring programs may not include receiving water monitoring. Recommended change:

    "d. Full implementation of the stormwater monitoring program shall begin within 6 months after the QAPP is approved by Ecology or within 36 months after the effective date of the permit, whichever is later."

16. Page 42, lines 22 – 24, Section S8.E.1.e. Seattle recommends that completion of S8.C. BMP Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring Program be extended as the current timeline is unrealistic. Assuming a permittee has monitorable, approved BMPs in the ground at the time the permit is issued, for a collaboratively developed program a realistic timeline would be:

    End of Year 1 – Commitment to collaborative process
    End of Year 2 - Submit QAPPs to Ecology
    Year 3 – 3.5* – Ecology approved QAPP (* remaining timeline based on when Ecology approves QAPP)
    Year 3.5 – End of Year 3 – Install and trouble shoot monitoring equipment.
    Year 4 - 7.5 – Collect data. It could take up to three years to collect data for BMP monitoring. Worst case, assume 35 samples needed. At 10 storm samples/year, it would take 3.5 years

    Year 7.5 – End of Year 7 – Analyze data and write report. End of Year 7 is equivalent to 4.5 years after QAPP is approved.

    Recommend change:

    "e. Data collection and analysis for S8.C. Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring Program that have been completed during the permit term must be submitted to Ecology no later than the fifth-year Monitoring Report. The fifth-year Monitoring Report will also describe Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring Programs that are still in progress as of the end of the reporting period."

17. Page 42, lines 30 – 31, Section S8.E.2.b. Seattle recommends establishing timeline for Permittee to respond to Ecology comments on QAPP. Same rational as for collaboratively monitoring discussed above. Recommended change:

    "b. Ecology will review QAPPs and provide a written response to the Permittee. If a QAPP is not approved, the Permittee will revise the QAPP within two months of receiving written comments from Ecology and resubmit QAPP for approval. Ecology will review resubmitted QAPPs and provide a written response to the Permittee."

18. Page 42, lines 32 -33, Section S8.E.2.c. Seattle recommends linking implementation of the monitoring program to approval of the QAPP. Same rational as for collaboratively monitoring discussed above. Recommended change:

    "c. Full implementation of the stormwater monitoring program shall begin no later than 6 months after the QAPP is approved by Ecology or within 24 months after the effective date of the permit, whichever is later."

19. Page 42, lines 34 – 36, Section S8.E.2.d. Seattle recommends that completion of S8.C. BMP Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring Program be extended as the current timeline is unrealistic. Assuming a permittee has monitorable, approved BMPs in the ground at the time the permit is issued, for an independently developed program a realistic timeline would be:

    End of Year 1 - Submit QAPPs to Ecology
    Year 2 – 2.5* – Ecology approved QAPP (* remaining timeline based on when Ecology approves QAPP)
    Year 2.5 – End of Year 2 – Install and trouble shoot monitoring equipment.
    Year 3 - 6.5 – Collect data. It could take up to three years to collect data for BMP monitoring. Worst case, assume 35 samples needed. At 10 storm samples/year, it would take 3.5 years
    Year 6.5 – End of Year 6 – Analyze data and write report. End of Year 6 is equivalent to 4.5 years after QAPP is approved.

    Recommended change:

    "d. Data collection and analysis for S8.C. Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring Program that have been completed during the permit term must be submitted to Ecology no later than the fifth-year Annual Report. The fifth-year Annual report will also describe Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring Programs that are still in progress as of the end of the reporting period."

20. Page 42, line 38 – Page 43, line 2, Section S8. F.1. Seattle recommends that stormwater monitoring report be submitted based on calendar year and due at the same time as the Annual Report (Section S9.B) on May 1 of each year. From a technical perspective, it is not necessary to report monitoring based on wet years. From a personnel management perspective, it is preferred that the Monitoring Report not be due at the end of the year. From a consistency perspective, it is recommended that the Monitoring Report on the same cycle as the Annual Report for cost reporting purposes. Additionally, cost reporting for monitoring should be done on a calendar year to be consistent with cost reporting requirements in the Annual Report and should be included in the Annual Report instead of the Monitoring Report.

    Regardless of whether stormwater monitoring is based on calendar year or wet year, there needs to be sufficient time to do the following necessary tasks once the sample collection period ends:

    - Receive and provide quality assurance review of laboratory samples (1 month)
    - Analyze data (1 month)

- Write draft/final annual monitoring report (1 month),
- Internal review (2 weeks)

In total, this is approximately 4 months. Thus, if reporting period is calendar year, Seattle recommends annual report to Ecology on May 1. This would coincide with the submittal of the annual report. Recommended change:

> "1. The stormwater monitoring report shall be submitted by May 1st each year beginning in 2009 for independent monitoring, and 2010 for collaborative monitoring. Each report shall include all monitoring data collected during the preceding period from January 1 through December 31. Each report shall also integrate data from earlier years into the analysis of results, as appropriate. Permittees that choose to participate in an integrated water quality monitoring program shall submit a single integrated monitoring report. Reports shall be submitted in both paper and electronic format and shall include:"

21. Page 43, lines 7 – 16, Section S8.F.1.a. Seattle recommends deleting this section since we recommend deleting Section S8.A Stormwater Monitoring.

22. Page 44, lines 8 – 11, Section S8.F.1.d. Seattle recommends moving this section to Annual Report (Section S9.B). This would present the monitoring program costs in context of other costs associated with the Permittee's Stormwater Management Program. Monitoring costs would be incorporated into Form 3-2. Expenditure Report Form (Appendix 3 – Phase I Municipal Stormwater General Permit).

23. Page 44, lines 12 – 13, Section S8.F.2. Seattle recommends clarifying that additional data to be included for monitoring stations associated with monitoring programs in Section S8A, S8B, and S8C. It is unreasonable to expect Permittee to include all pollutant (e.g., TSS) collected by the Permittee anywhere in its jurisdiction. As with other public records, Permittees' monitoring records are available upon request according to the public disclosure law. This makes the additional reporting requirement in the last sentence of S8.F.2 unnecessary. Such requirements arose for permits with a limited number of outfall locations. In contrast, for municipal stormwater, the requirement would be a considerable burden. Permittees may conduct decentralized monitoring for many reasons under other regulatory requirements or voluntary initiatives, such as related to Superfund cleanups, construction or industrial stormwater permits, pilot programs, routine complaint investigations, educational programs, etc. Even the meaning of "monitoring" may be debatable, making compliance unreasonably difficult. Recommended change:

    > "2. If the Permittee monitors any pollutant more frequently at monitoring stations associated with the monitoring programs described in Sections S8.A *(if this requirement is not deleted)*, S8.B, and S8.C, then the results of this monitoring shall be included in the report."

References

PSAT. 2005. Low Impact Development Technical Guidance Manual for Puget Sound. Puget Sound Action Team and Washington State University Pierce County Extension. Publication No. PSAT 05-03.

Introduction

As discussed in Seattle's comments, Seattle opposes the event mean concentration (EMC)-based stormwater monitoring proposed in Section S8.A on the principle that it will produce few, if any, benefits while incurring high costs over an extended period of time. This section describes the reasons for Seattle's opposition, provides illustrative examples, and presents a rough estimate of the likely costs involved to meet the intent of the requirement should Ecology chose to retain it.

The Stated Intent of Pollutant Load Analysis

In the draft permit, Ecology states that:

> *"The results of the monitoring program shall be used to support the adaptive management process and lead to refinements of the Stormwater Management Program." (Draft Permit, Special Condition 8)*

In the Fact Sheet, Ecology further explains that:

> *"Knowledge of pollutant loads and of average event mean concentrations from representative areas drained by the municipal storm sewer systems are necessary to gauge whether the comprehensive stormwater management programs are making progress towards the goal of reducing the amount of pollutants discharged and protecting water quality." (Draft Fact Sheet, page 49)*

Ecology's views in the permit and fact sheet are also consistent with EPA's 1990 preamble to the federal rule, where EPA indicates that:

> *"…an estimate of annual pollutant loading associated with discharges from municipal stormwater systems is necessary to evaluate the magnitude and severity of the environmental impacts of such discharges and to evaluate the effectiveness of controls which are imposed at a later time." (*See pages 48049-48052 of the Federal Register, Volume 55, No. 222, November 16, 1990)

The intent of pollutant load analysis, therefore, is to characterize the runoff so that a trend can be observed and management decisions made regarding a jurisdiction's stormwater program or Ecology's permit requirements.

What's wrong with pollutant load trend analysis?

However laudable and reasonable sounding Ecology's and EPA's objectives are in principle, they will be difficult, if not impossible, to achieve due to the high variability of pollutant concentrations in stormwater runoff. Pollutant concentrations in stormwater runoff are so variable that our analysis indicates that it would take hundreds of event mean concentration (EMC) samples over many years of sampling to *even begin to meaningfully establish a necessary baseline* measure of pollutant concentrations. A baseline measure is only the first step in trend analysis. Determining trends beyond the baseline will take additional samples. Adding to the complications of pollutant loading trend analysis is the fact that a pollutant load is the product of average concentration *and* the total flow during the period. Inaccuracies in estimating total annual flow volumes — capable of exceeding 20% or more — will further frustrate long-term trend analysis when the anticipated trends we are looking for are on the order of 10% or less. Even if flow volumes could be accurately measured each year, the variability in annual total rainfall between years will add additional complications to the trend analysis. For example, drought periods can indicate downward trends in annual pollutant loads when the root cause is not low EMCs but less runoff. Taken together, these factors support our contention that to meet the stated objective, extensive data would have to be collected — a costly undertaking — over a long period of time and, even then, the ability to detect a true trend may not be possible.

A predictable counter-argument to the above reasoning is that if trend analysis will require so many data, better to start collecting those data earlier rather than later. Given that Ecology may subscribe to this view, presented below is Seattle's understanding of what trend monitoring will entail so that Ecology fully understands the implications of such a decision.

How variable is stormwater?

The information below is derived from Chandler (1995, 1999). These documents contain statistical analyses of urban runoff storm event mean concentrations (EMCs) collected from 43 different sites in western Washington and western Oregon. The sites were determined to be representative of three different land uses: residential (20 sites), commercial (15 sites), and industrial (8 sites). Statistical tests were first conducted verifying that the data from these sites could reasonably be combined into a single data set for further analysis. The combined data sets were then subjected to a detailed analysis that produced a compilation of summary statistics, which included maximum and minimum observations, mean, median, variance, and 95% confidence limits (high & low) around the predicted mean.

The results from this study illustrate the variability inherent in runoff concentrations. For example, consider the EMCs for total suspended solids (TSS) from residential sites, the constituent with the most observations (91) of any parameter. The 91 different TSS concentrations from samples taken from 20 different sites ranged across *three* orders of magnitude, from 2 mg/l to 2300 mg/l[1]. Using total recoverable zinc as a second example, the highest recorded EMC for residential land use (86 observations from 20 different sites) was 500 times the lowest EMC. The study further calculated the average EMC for each parameter[2] for each land use and then estimated the high and low limits for the predicted average using a standard 95% confidence level. Despite the relatively large amount of data available, the high and low ranges often spanned a factor of two or more. For example, based on the 91 observations, we can be 95% confident that an EMC for residential TSS in western Washington and Oregon will fall somewhere between 106.57 mg/l and 229.61 mg/l.

How many samples must be taken before a trend can be observed?

To evaluate trends using data that are highly variable, it is better to use the median, rather than the mean. This is because statistically speaking, the average (or mean) is highly influenced

[1] As a side note of interest, the site at which the highest value of 2300 mg/l EMC TSS was observed also had one of the lowest measured TSS values of 9 mg/l among its 15 observations.

[2] There were nine constituents selected for this analysis: Total Suspended Solids, Total Dissolved Solids, Chemical Oxygen Demand, Total Recoverable Phosphorus, Biochemical Oxygen Demand (5-day), Total Recoverable Copper, Total Kjeldahl Nitrogen, Total Recoverable Lead, and Total Recoverable Zinc

both by extreme values at the high end (consider the residential TSS example in the above paragraph) and by non-detectable samples (i.e., samples with pollutant concentrations below our ability to measure) at the low end. The median of a sample set, in comparison, is less influenced by such outlying values. The analysis below assumes that we are looking for trends in annual loads based on the flow volumes and median EMCs. Note that trend analysis requires that we collect enough EMC data so that a trend can actually be seen over time despite the variability among individual samples. For example, if the objective is to measure a trend where we expect a 10% change in pollutant EMCs, then it follows that enough samples will have to be collected to estimate the median EMC with an accuracy of 10% or better. The formula for approximating the number of independent observations needed to estimate the median within a certain percentage is given by Gilbert (1987) and Hale (1972):

$$n = \frac{Z^2{}_{(1-a/2)} * s_y^2}{[\ln(d+1)]^2 + Z^2{}_{(1-a/2)} S_y^2 / N}$$

Where: d is the pre-specified relative error in the estimated median that can be tolerated (5% or 10%);
100(1-a/2) is the percent confidence required that this error is not exceeded;
S_y^2 is the variance of the transformed (i.e., into logarithmic values) data set;
Z is the critical t-value for Student's t-Test (1.960 for 95% confidence level; and
N is the size of the population (assumed to be very large).

Table 6B.1 shows the number of samples needed to estimate the median within 5% and 10% at a given confidence level of 95%. It is based on the approach above and assumes the variances determined by Chandler (1995, 1999) for the Washington and Oregon urban pollutant EMCs collected between 1986 and 1994 will be similar to the variances that will be found during future sampling efforts.

Assume, for example, that Ecology wants to be 95% confident that a trend is present and that this trend is expected to be on the order of 10% (upward or downward). It follows, then, that the median would have to be estimated within 10% or better in order for such a trend to emerge from among the data scatter. Table 6B.1 shows that to observe an upward or downward trend of 10% of TSS in a residential basin with 95% confidence, Ecology would need approximately 939 independent samples. Among the metal constituents in Table 6B.1, residential EMC for total recoverable copper has one of the lowest variances (0.77), which means that only 326 samples are required to estimate the median within 10%. A 10% reduction in a short period of time, however, is a remarkable achievement for any stormwater management program. If the trend was more likely to be on the order of, say, 5%, then the copper example above would require 1243 independent samples before such a trend may become visible. Residential TSS would require 3,583 samples. This brings us to the second question:

<u>How long will it take and how much will it cost to see a trend of 5% or 10%?</u>

Assume that the variance among the all the EMCs is 1.25[3] and that we are looking for a trend up or down of 10%. Based on the formula above, approximately 529 samples are needed before the median can be estimated within 10%. Assuming that 15 samples are taken each year at a site (the number required by the permit if 20 or more qualifying storm events occur in a year), it will take approximately:

[3] Roughly the average variance for all nine parameters analyzed in Chandler (1995, 1999)

$$\frac{529 samples}{15 samples / year} \approx 35 years$$

Based on preliminary cost estimates provided by several other Phase I jurisdictions and Ecology, the laboratory costs associated with the Stormwater Monitoring requirement is between $1,000 and $1,500 for each sample. The draft permit requires monitoring at three different representative sites for each of the six Phase I permittees, and one site each for Port of Tacoma and Port of Seattle. A conservative (i.e., low) rough cost estimates in personnel, equipment, and other resources needed to establish these sites, collect the data during storm events, and manage the reporting and recording requirements range from $50,000 to $150,000 per year per permittee (for comparison, Seattle estimates implementation [i.e., data collection] of S8.A will cost between $225,000 and $275,000 per year [Attachment 6C]). Using the conservative rough cost estimates, the annual cost for eight permittees to collect 15 samples each year from a total of 20 different sites is between $700,000 and $1,650,000. [4]
Assuming the requirement remains unchanged for the 35 years and using an annual discount rate of 3% (compounded monthly):

> *The net present value of the cost to collect enough data over 35 years to estimate the true median within 10% is between $182,000,000 and $429,000,000.*

Given the likely low rate of change over time for urbanize settings like Seattle, an improvement in EMC pollutant concentrations of 10% over the sampling period would be an admirable achievement. Our concern is that any possible trends will be lost in the inherent statistical noise of the data even at this level. If we are, instead, hoping to see a trend of 5% using EMCs, then 2017 samples are needed to estimate the true median within 5%. This will take approximately:

$$\frac{2017 samples}{15 samples / year} \approx 135 years$$

Assuming the requirement remains unchanged for this period and based on the same arguments above.

> *The net present value of the cost to collect enough data over 135 years to estimate the true median within 5% is between $275,000,000 and $648,000,000.*

For each of the examples above, the staggering number of samples represents only the number of EMCs needed to estimate the median within 5% or 10%. To see a trend in the data, more samples will be needed. To account for inaccuracies in annual flow volume calculations and to

[4] Low estimate:

$$\frac{15 samples}{site} * \frac{20 sites}{year} * \frac{\$1,000}{sample} + \frac{\$50,000}{permittee} * 8 permittees = \$300,000 + \$400,000 = \$700,000$$

High estimate:

$$\frac{15 samples}{site} * \frac{20 sites}{year} * \frac{\$1,500}{sample} + \frac{\$150,000}{permittee} * 8 permittees = \$450,000 + \$1,200,000 = \$1,650,000$$

address complications in trend analysis caused by annual variations in rainfall volumes, even more samples will be required.

Can we use the combined data from all Permittees for trend analysis?

Having made the case against pollutant load trend analysis on the basis of the high volume of EMCs required to characterize each site, why not simply combine the data from each of the representative land uses and use the larger data set to characterize the runoff?[5] For example, Ecology could receive as many as eight sets of annual pollutant load calculations for commercial sites. This means that instead of only having 15 samples each year for each site, Ecology could have as many as 120 samples for all sites having the same land use. Using the same method as above, one could argue that instead of 35 years to estimate the median within 10% or 135 years to estimate the median within 5%, the time could be shaved to less than five years (10% accuracy) and less than 17 years (5% accuracy). Although plausible in concept, there are three issues that would have to be considered before steering this course:

1. Load calculations are highly dependent on the flow characteristics of each individual site — size, imperviousness, rainfall patterns, the presence of BMPs, to name a few. To establish a statewide trend analysis, some statistical method(s) will have to be employed to normalize the collective data each year in order to account for the variability among sites.
2. The number of samples needed to estimate the median with a 5% or 10% accuracy depends on the variance of the data. By combining data for several different sites, it is possible that the statistical variance among the data will increase, thereby increasing the number of samples needed. Employing the equation described above, but using a variance of 1.50 rather than 1.25, the number of required samples increases from 529 to 634 (10% accuracy) and 2017 to 2421 (5% accuracy).
3. A trend in pollutant loading statewide may mask the more important trends occurring on a site scale. For example, Ecology may determine that there is an overall downward trend in annual loading statewide for a pollutant of interest. However, this trend may be caused by a small number of sites achieving a significant reduction, thereby skewing the overall trend when, in actuality, the majority of sites are holding steady. In trend analysis, the more intriguing question is often not, "what is the overall trend?" but, rather, "why is the trend for this one site so different from the trend in another, seemingly similar site?"

Even we got all the needed data, would that help refine Stormwater Management Programs?

The true crux of the argument regarding the value of pollutant load analysis lies not in the amount of data needed, although that is a legitimate consideration, but on whether the information garnered from the effort is actually useful. A large collection of stormwater data may produce amazing box plots, intriguing graphs, and an abundance of correlation coefficients, but the data are of no value to the stormwater profession unless the results influence a programmatic or regulatory decision. More importantly, value is achieved only if the data lead

[5] This is essential what was done by Chandler (1995, 1999) to develop statistical summaries (mean, median, variance, confidence levels, etc.) for each parameter.

us to make the *right* decision. Both EPA and Ecology correctly state that the intent of representative runoff monitoring is to gauge programmatic progress, refine stormwater management programs, and evaluate effectiveness of controls. We believe that using stormwater pollutant load analysis can, indeed, support stormwater management decision-making, provided that sufficient data can be obtained so that the decisions are based on sound science and robust statistical analysis. However, detailed analysis of a large quantity of data obtained at great expense over an extended time period may not be the best way to support stormwater management decision-making. Two final considerations on this point:

1. Do we need the data before we can make a decision? Seattle contends that neither stormwater managers nor stormwater regulators need representative runoff data to see where the majority of the problems are and to take reasonable actions to address them. In Seattle, our creeks are impacted more by high flows than by pollutant loads and our programmatic actions and capital projects are aimed at managing this challenge. Our larger receiving waters suffer from sediments contaminated by past historic practices, and we are engaged with other stakeholders to address this problem. We know that to reduce stormwater pollution to the maximum extent practicable requires a comprehensive and coordinated suite of programmatic activities that include reducing pollutants at the source, constructing new treatment and flow control facilities, maintaining existing facilities, enforcing regulations, and educating our public. Data regarding pollutant loads and trends will not add meaningfully to what we already know in this regard.
2. What are we trading in exchange for the additional data? A total net present value of $648,000,000 is a significant sum for statewide stormwater management programs. More to the point, for Seattle to meet the stormwater monitoring requirement, we estimate staff, laboratory, and other resource needs will cost Seattle over $750,000 during the five year permit term. We contend that three-quarters of a million dollars could be put to better use, particularly when considering the fact that the data will not yield fruit for years, perhaps decades, and perhaps longer, if at all.

Summary

Taken together, the following factors support our contention that pollutant loading and EMC-based trend analysis will be a costly undertaking that will produce a significant quantity of data but result in very little, if any, useful information in the near term and may not support management decisions needed in the longer term.

5. Stormwater runoff concentrations are highly variable, capable of spanning several orders of magnitude at a single site.
6. Owing to this variability, a significant amount of data must be collected over many years before a trend can be determined. On a per-site basis, the number needed ranges from many hundreds to several thousands of samples per site for each parameter of interest.
7. The costs involved in collecting these data will draw funds away from other stormwater programs. Seattle estimates implementation (i.e., data collection) for

S8.A will cost between $225,000 and $276,000 per year (Attachment 6C). Using a conservative (i.e., low) range estimate of between $100,000 and $200,000 per year per permittee, the estimated net present value of the data collection effort of all Phase I Permittees over a period spanning many years exceeds nearly $200,000,000 and is probably much higher.

8. Even if a trend could be determined at the cost estimated above, it is unclear the degree to which this trend would actually influence decision-making at the programmatic and regulatory scale.

References

Chandler, R.D., 1995. *Improving Urban Stormwater Runoff Monitoring Practices,* Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Washington, Seattle, Washington.

Chandler, R.D., 1999. "The Case against Representative Stormwater Runoff Monitoring," Wilson, E. M. (Ed.). *Proceedings* of the 26th Annual Water Resources Planning and Management Conference, June 6 - 9, 1999. Tempe, Arizona. American Society of Civil Engineers.

Gilbert, R.O., 1987. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold, New York

Hale, W.E., 1972. "Sample Size Determination for the Log-Normal Distribution." *Atmospheric Environment* 6:419-422.

Table 6B.1 Estimating the True Median: How Many Independent Samples are Required?

Background: The table below indicates the number of independent samples that must be collected to estimate the true median of a particular pollutant concentration within a certain percent relative error. For example, using the table below, if one wants to be 95% confident that the estimated median of TSS concentrations in a residential basin is within 10% of the true median, approximately 939 independent samples must be taken. Note that for pollutant concentrations, the median, rather than the average, is the best measure of the central tendency because the median is less affected by extreme values. Notes regarding these calculations are given at the bottom of the page.

Constituent	TSS - R	TSS - C	TSS - I	Cu - R	Cu - C	Cu - I	Pb - R	Pb - C	Pb - I	Zn - R	Zn - C	Zn - I
Variance (log) = S^2	2.22	1.15	1.28	0.77	0.81	1.53	1.15	1.56	1.76	0.99	0.85	1.34
Case 1: 95% Confidence												
Percent Confidence	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
a	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
a/2	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
(1-a/2)	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975
Z	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960
Option a: 10% Error												
Relative Error	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Number of Samples	939	486	541	326	343	647	486	660	744	419	359	567
Option b: 5% Error												
Relative Error	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of Samples	3583	1856	2066	1243	1307	2469	1856	2518	2840	1598	1372	2162

Constituent	BOD - R	BOD - C	BOD - I	COD - R	COD - C	COD - I	TP - R	TP - C	TP - I	TKN - R	TKN - C	TKN - I
Variance (log) = S^2	1.04	1.53	1.39	1.13	1.59	0.64	1.50	1.36	1.58	0.52	0.71	0.34
Case 1: 95% Confidence												
Percent Confidence	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
a	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
a/2	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
(1-a/2)	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975	0.975
Z	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960
Option a: 10% Error												
Relative Error	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Number of Samples	440	647	588	478	672	271	634	575	668	220	300	144
Option b: 5% Error												
Relative Error	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of Samples	1678	2469	2243	1824	2566	1033	2421	2195	2550	839	1146	549

Notes:

(1) The formula for approximating the number of independent observations needed to estimate the median of a lognormal distribution is from Gilbert (1987) and Hale (1972):

$$n = \frac{Z^2_{(1-a/2)} * s_y^2}{[\ln(d+1)]^2 + Z^2_{(1-a/2)} S_y^2 / N}$$

Where: d is the pre-specified relative error in the estimated median that can be tolerated;
100(1- a)% is the percent confidence required that this error is not exceeded;
s_y^2 is variance of the transformed (i.e., into logarithmic values) data set;
Z is the critical t-value for Student's t-test; and
N is the size of the population (assumed to be very large)

(2) Values given above for variance of the transformed data set are based on Chandler (1995), wherein statistical analyses of EMC values from Western Washington and Western Oregon were performed. It is assumed that the variances determined in this study have not appreciably changed.

(3) Total Suspended Solids (TSS), Total Recoverable Copper (Cu), Total Recoverable Lead (Pb), and Total Recoverable Zinc (Zn). Biochemical Oxygen Demand (5-day) (BOD), Chemical Oxygen Demand (COD), Total Recoverable Phosphorus (TP), Total Kjeldahl Nitrogen (TKN).

References:

Chandler, R.D., 1995. *Improving Urban Stormwater Runoff Monitoring Practices,* Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Washington, Seattle, Washington.

Gilbert, R.O., 1987. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold, New York

Hale, W.E., 1972. "Sample Size Determination for the Log-Normal Distribution." *Atmospheric Environment* 6:419-422.

Attachment 6C. Seattle's Preliminary Cost Estimate for S8. Monitoring

Alternative	Section	Resource	2007	2008	2009	2010	2011	TOTALS 2007 - 2011
Alternative 1. All SPU (no consultants)	Stormwater Monitoring (S8.A)	*SPU labor (FTE)*	*0.4*	*0.1*	*1.8*	*1.8*	*1.8*	***5.9***
		non-labor ($)	*$0*	*$45,000*	*$45,000*	*$45,000*	*$45,000*	***$180,000***
		SPU labor* + non-labor ($)	$39,375	$58,125	$225,000	$225,000	$225,000	**$772,500**
	SWMP Effectiveness Monitoring (S8.B)	*SPU labor (FTE)*	*0.5*	*0.2*	*1.7*	*1.7*	*0.0*	***4.0***
		non-labor ($)	*$0*	*$60,000*	*$12,000*	*$12,000*	*$0*	***$84,000***
		SPU labor* + non-labor ($)	$52,500	$77,500	$177,000	$177,000	$0	**$484,000**
	BMP Evaluation Monitoring (S8.C)	*SPU labor (FTE)*	*1.0*	*0.3*	*3.3*	*3.3*	*3.3*	***11.1***
		non-labor ($)	*$0*	*$135,000*	*$40,000*	*$40,000*	*$40,000*	***$255,000***
		SPU labor* + non-labor ($)	$103,125	$169,375	$365,000	$365,000	$365,000	**$1,367,500**
	TOTAL	**SPU labor* + non-labor ($)**	**$195,000**	**$305,000**	**$767,000**	**$767,000**	**$590,000**	**$2,624,000**
Alternative 2. SPU oversight with majority of work by consultants	Stormwater Monitoring (S8.A)	*SPU labor (FTE)*	*0.2*	*0.1*	*0.2*	*0.2*	*0.2*	***1.0***
		non-labor ($)	*$41,250*	*$58,750*	*$255,000*	*$255,000*	*$255,000*	***$865,000***
		SPU labor* + non-labor ($)	$65,250	$66,750	$276,000	$276,000	$276,000	**$960,000**
	SWMP Effectiveness Monitoring (S8.B)	*SPU labor (FTE)*	*0.3*	*0.1*	*0.2*	*0.2*	*0.0*	***0.8***
		non-labor ($)	*$75,000*	*$85,000*	*$208,000*	*$208,000*	*$0*	***$576,000***
		SPU labor* + non-labor ($)	$100,500	$93,500	$229,600	$229,600	$0	**$653,200**
	BMP Evaluation Monitoring (S8.C)	*SPU labor (FTE)*	*0.4*	*0.1*	*0.3*	*0.3*	*0.3*	***1.5***
		non-labor ($)	*$183,750*	*$196,250*	*$442,000*	*$442,000*	*$442,000*	***$1,706,000***
		SPU labor* + non-labor ($)	$221,250	$208,750	$476,200	$476,200	$476,200	**$1,858,600**
	TOTAL	**SPU labor* + non-labor ($)**	**$387,000**	**$369,000**	**$981,800**	**$981,800**	**$752,200**	**$3,471,800**

Major Assumptions

Independent approach. A collaborative approach would have later deadlines.

S8.A only includes stormwater sampling collection and analysis. Sediment and toxicity sample collection and analysis is not included.

Does not account for ongoing projects/equipment which may meet monitoring requirements (e.g., street sweeping pilot, NDS monitoring)

Does not consider collaboration or monitoring projects that address more than one monitoring component that may decrease level of effort.

Refer to timeline as to assumptions made regarding duration of SWMP Effectiveness & BMP Evaluation monitoring

Assumptions for SWMP Effectiveness Monitoring: 2 projects, each which 2 stations, collecting 10 wq sample from storms/yr for 2 years.

* Assumed 1 FTE = $100,000/yr